Robust Communication for Air Traffic Control

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Overview

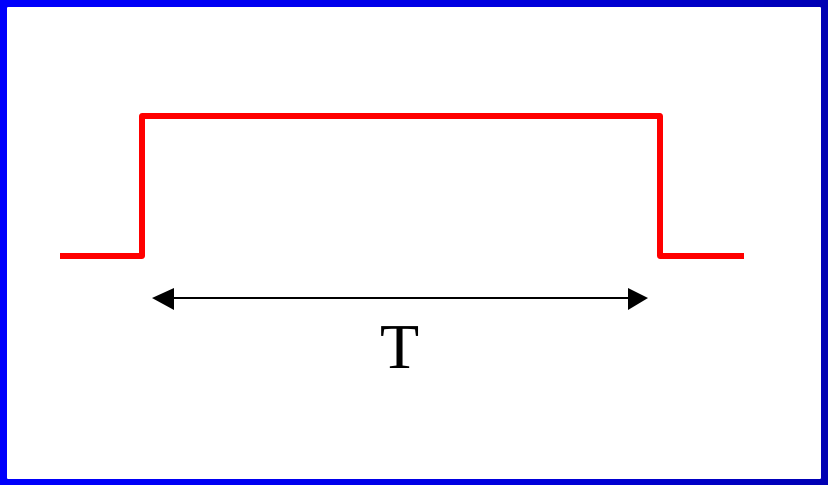
- Driving Factors in physical layer development
- Description of DSSS
- Explanation of near-far problem in DSSS
- Receiver for mitigating the near-far problem
- Simulation results

Driving Factors

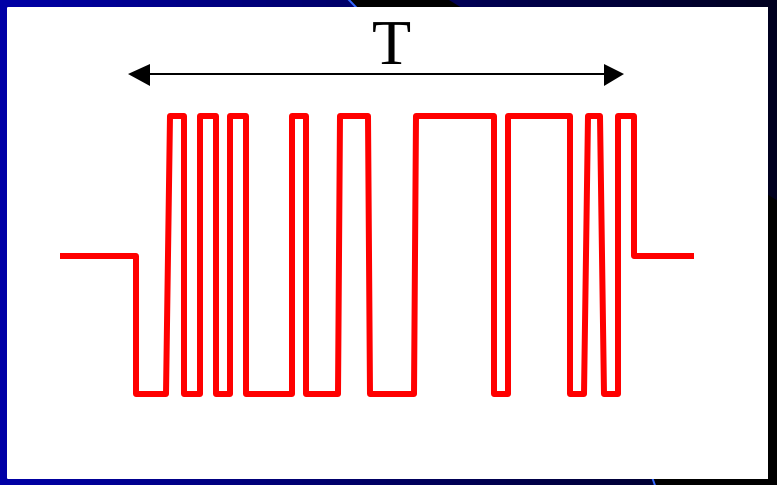
- Capacity to support increased services
- Security from eavesdropping
- Robust in the presence of noise/interference
- Easily upgradeable

Description of DSSS

Basic pulse

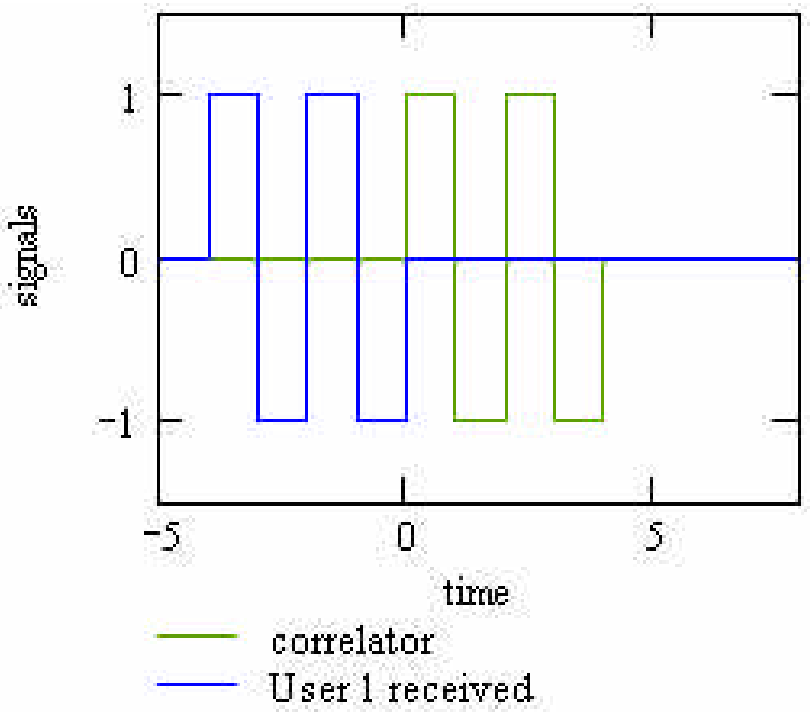


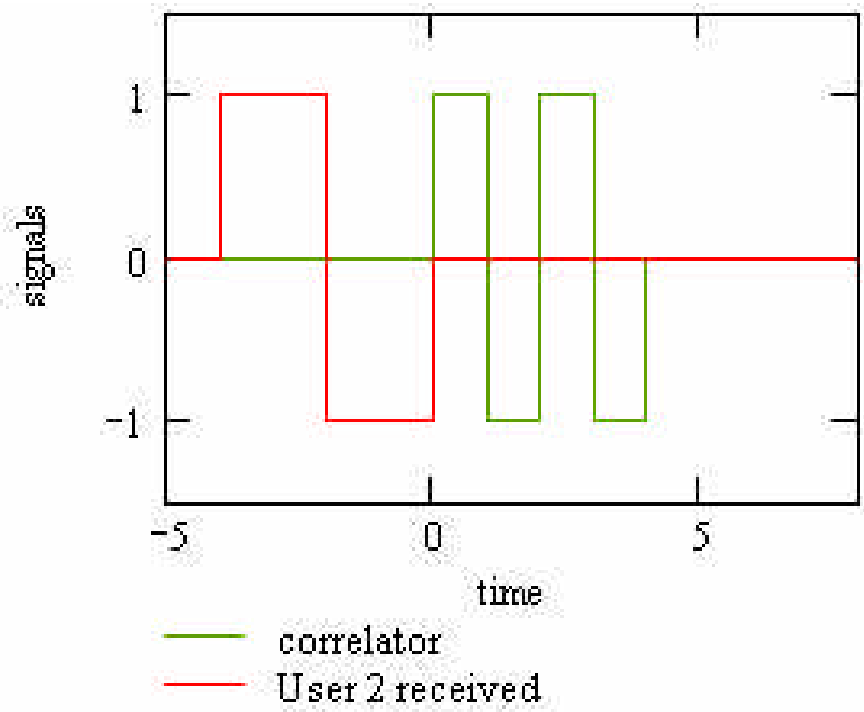
DSSS pulse

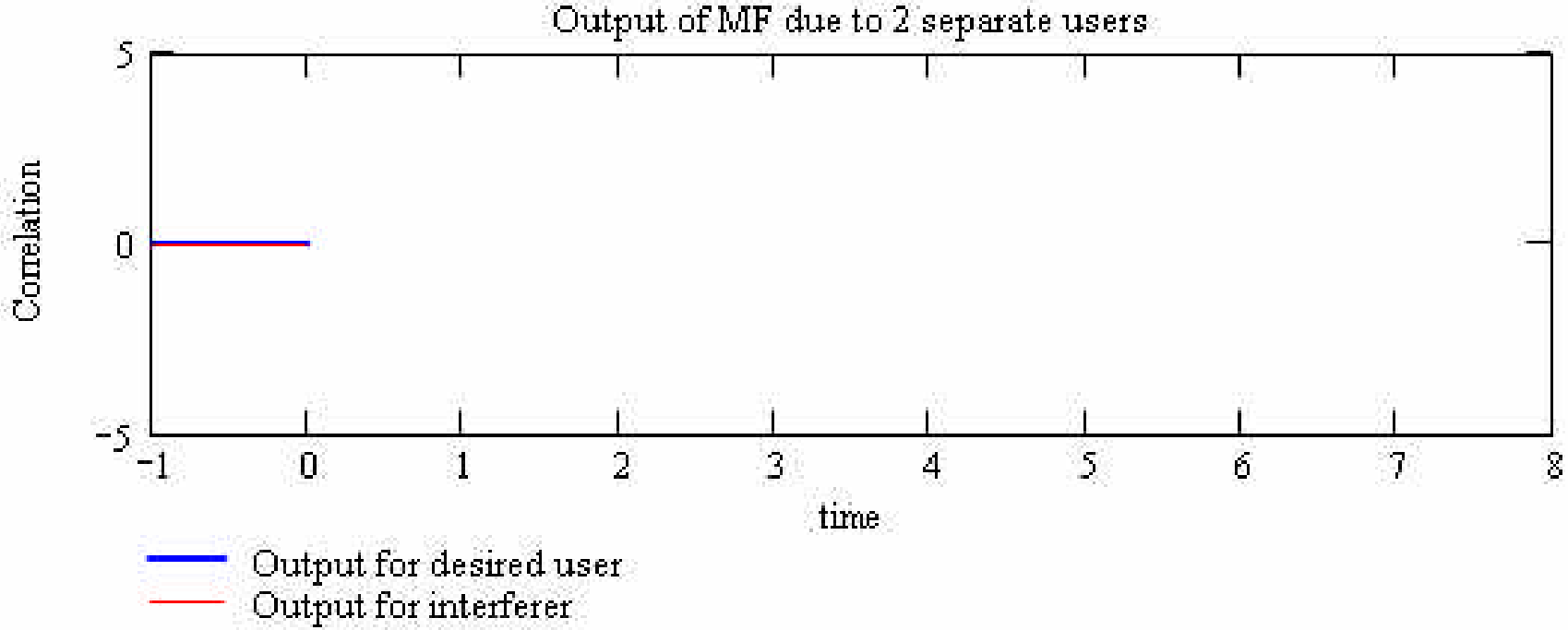


31 chips/symbol

CDMA


signals
1
0
-1
-5
0
5
time
correlator
User 1 received

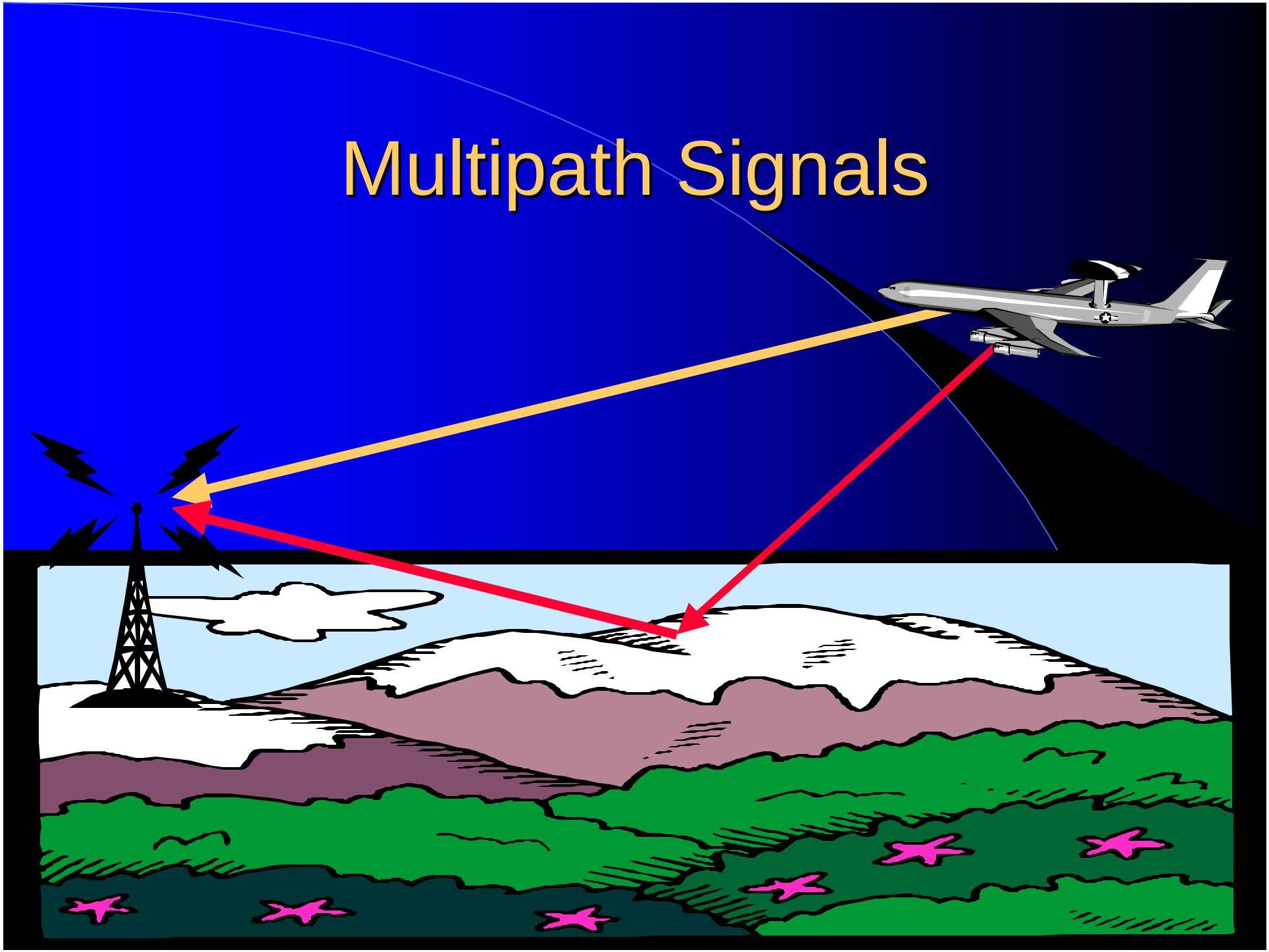

signals
1
0
-1
-5
0
5
time
correlator
User 2 received


Output of MF due to 2 separate users
Correlation
5
0
-5
-1
0
1
2
3
4
5
6
7
8
time
Output for desired user
Output for interferer

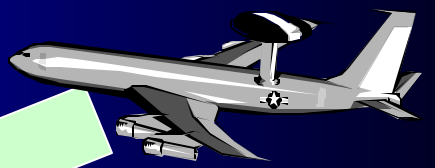
Capabilities of DSSS

- Code-Division Multiple-Access (CDMA)
- Narrowband interference suppression
- Codes provide security
- Multipath combining capability

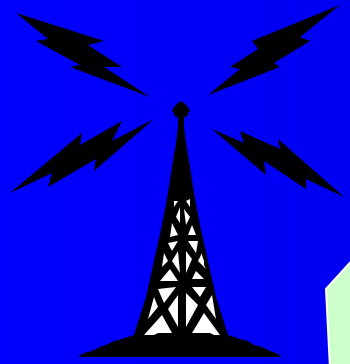
Multipath Signals



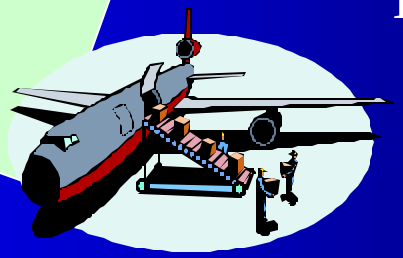
The Near-Far Problem



Large power loss



Small power loss



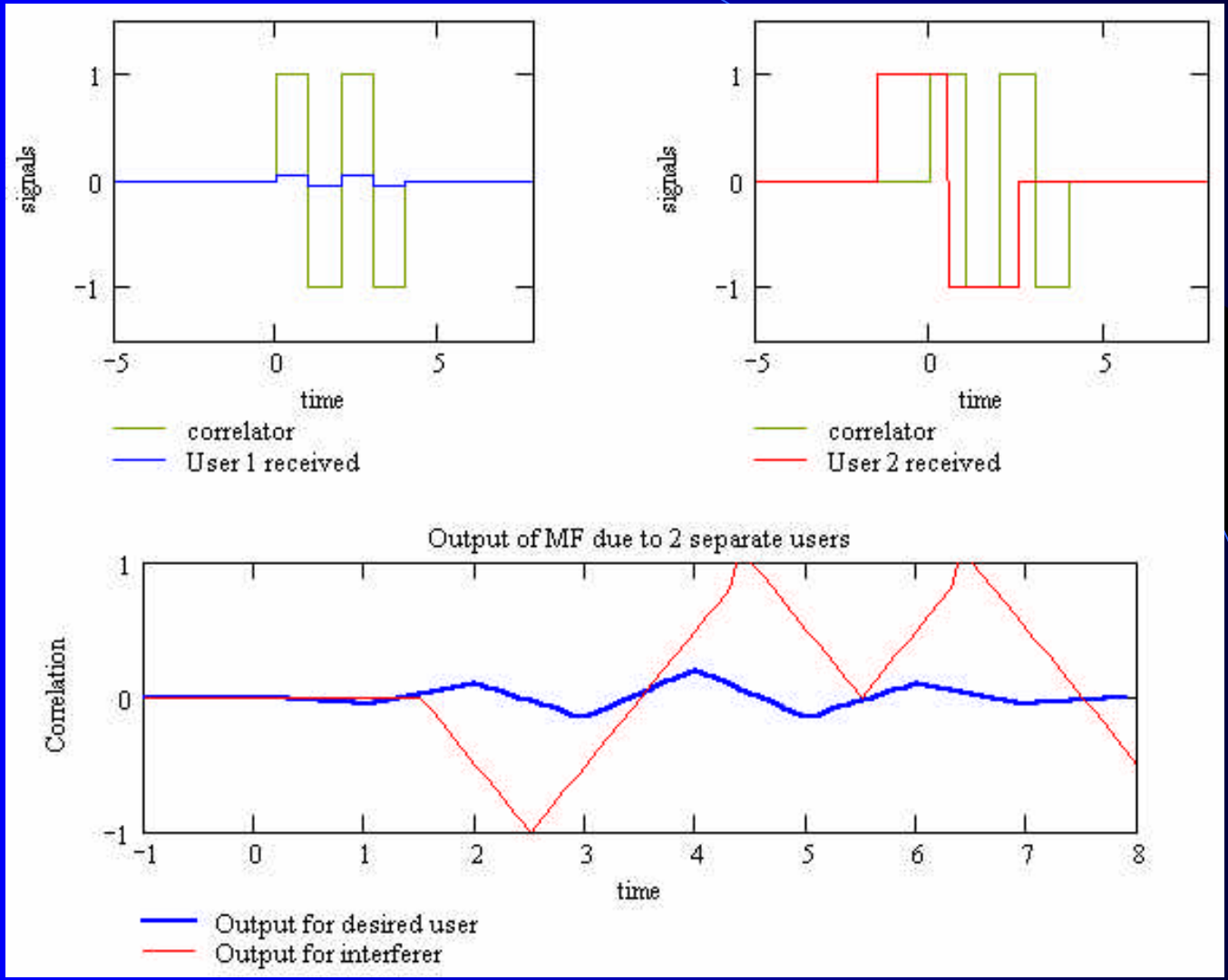
$d_{near} = 1 \cdot mile$

$d_{far} = 50 \cdot mile$

$P_{diff} = -33.979 \cdot dB$

Power is over 2000 times lower

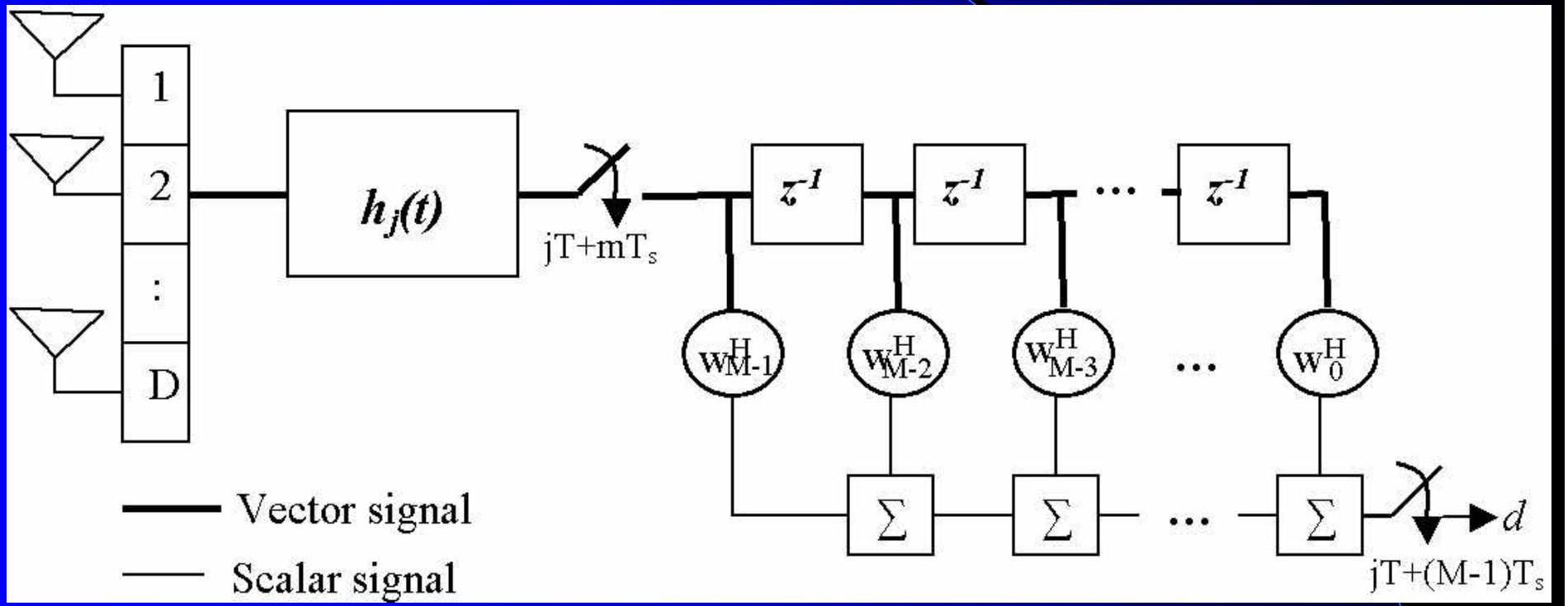
The Near-far Problem



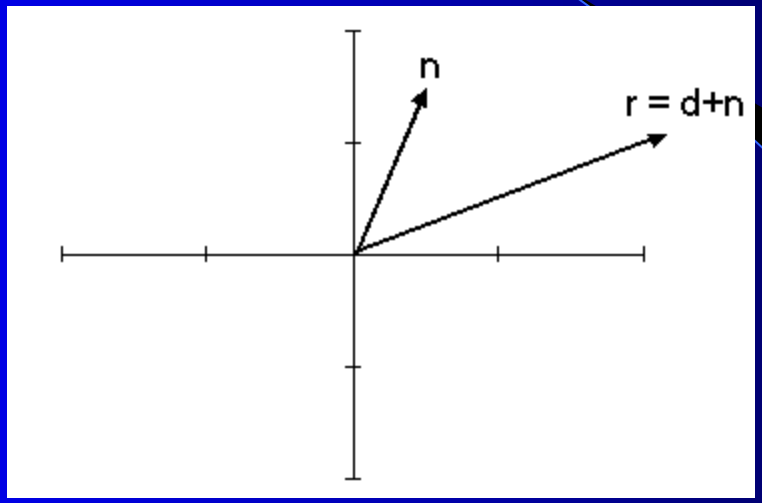
A Robust Receiver in MAI

- Maintains advantages of the conventional DSSS receiver
- Provides spatial division of users
- Improves near-far performance by suppressing multi-access interference
- Adapts to channel conditions

Proposed Receiver for ATC



Adaptive Algorithm

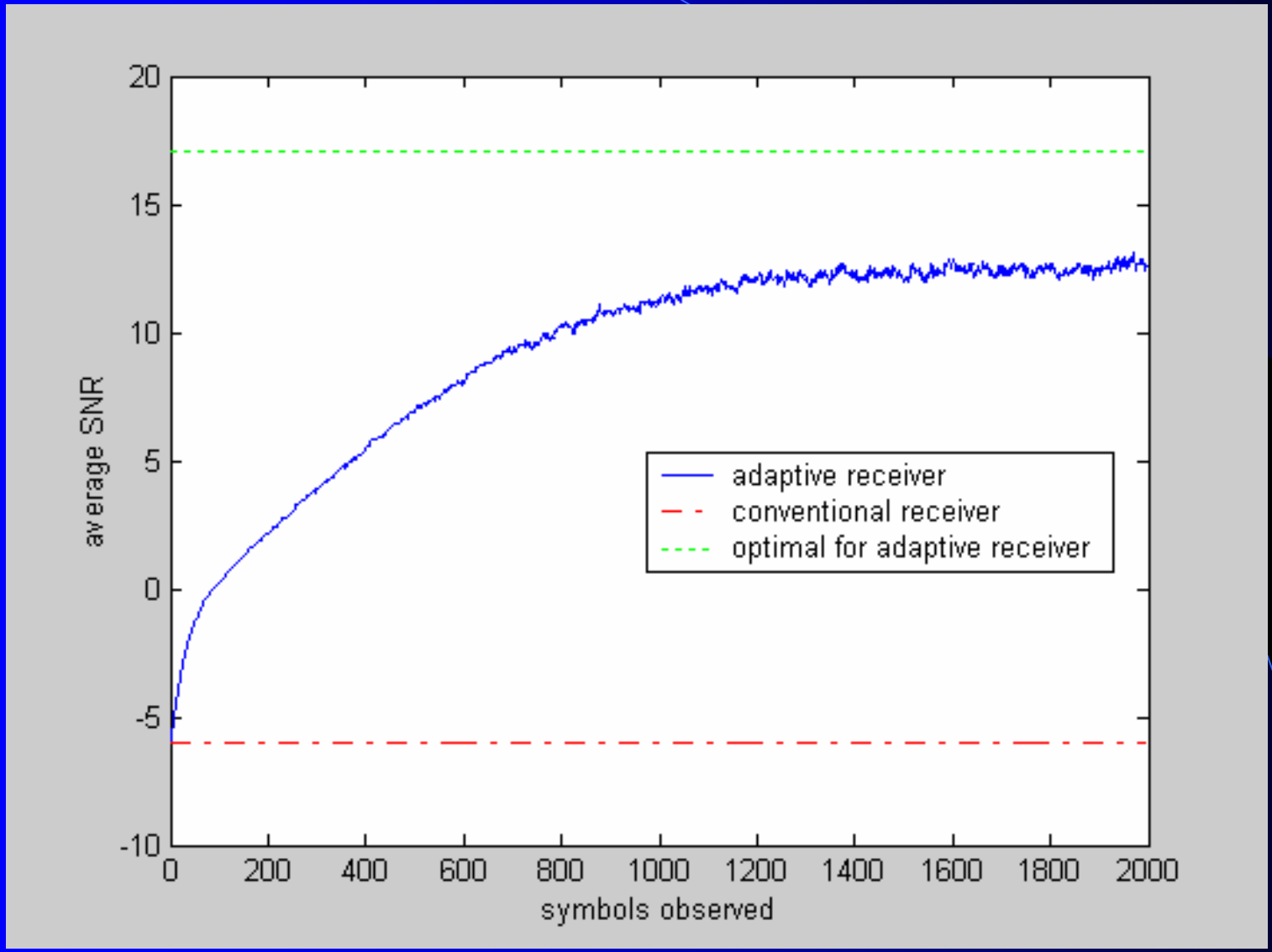


- Form a desired signal plus interference vector
- Form a vector of only interference
- Find the part or ***r*** that is orthogonal to ***n***

Simulation Results

- Processing gain= 21 dB -- (127 chips per symbol)
- 1 antenna
- Rectangular chip waveform
- 1 interfering user with 30 dB more power
- ½ chip delay for the interfering signal
- Sample matched filter at 4 time the chip rate
- Examine SNR over symbols and compare to a conventional matched filter receiver

Simulation Results



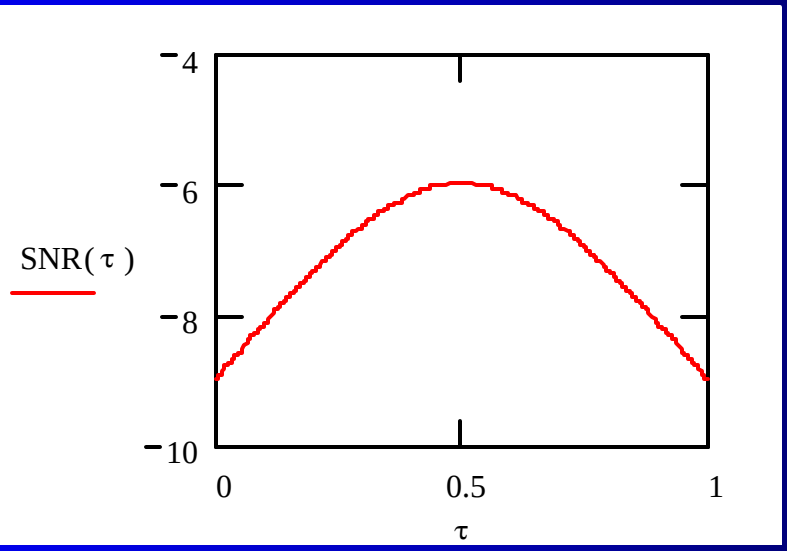
Conclusion

- DSSS is a good choice for future ATC
- Described the near-far problem of CDMA for ATC
- Described a linear receiver to improve performance in severe near-far situations

Questions

SNR Calculations

$$SNR(\tau) := 10 \cdot \log\left[\frac{E_b}{No + \left(E_b \cdot 1000 \frac{1}{N}\right) \cdot \left(2 \cdot \tau^2 - 2 \cdot \tau + 1\right)}\right]$$



References

[1] T. F. Wong, T. M. Lok, J. S. Lehnert, and M. D. Zoltowski, "A linear receiver for direct-sequence spread-spectrum multiple-access systems with antenna arrays and blind adaptation," *IEEE Trans. Inform. Theory*, vol. 44, pp. 659-676, Mar. 1998.

[2] T. F. Wong, T. M. Lok, and J. S. Lehnert, "Asynchronous multiple-access interference suppression and chip waveform selections with aperiodic random sequences," *IEEE Trans. Commun.*, vol. 47, pp. 103-114, Jan. 1999.

[3] S. Haykin, *Adaptive Filter Theory*, 3rd ed. Upper Saddle River, NJ: Prentice-Hall, 1996.

[4] D. W. Matolak, "CDMA for communications in the aeronautical environment," Digital Avionics Systems Conference, 16th DASC, AIAA/IEEE vol. 2 , pp. 21-27, Oct. 1997.